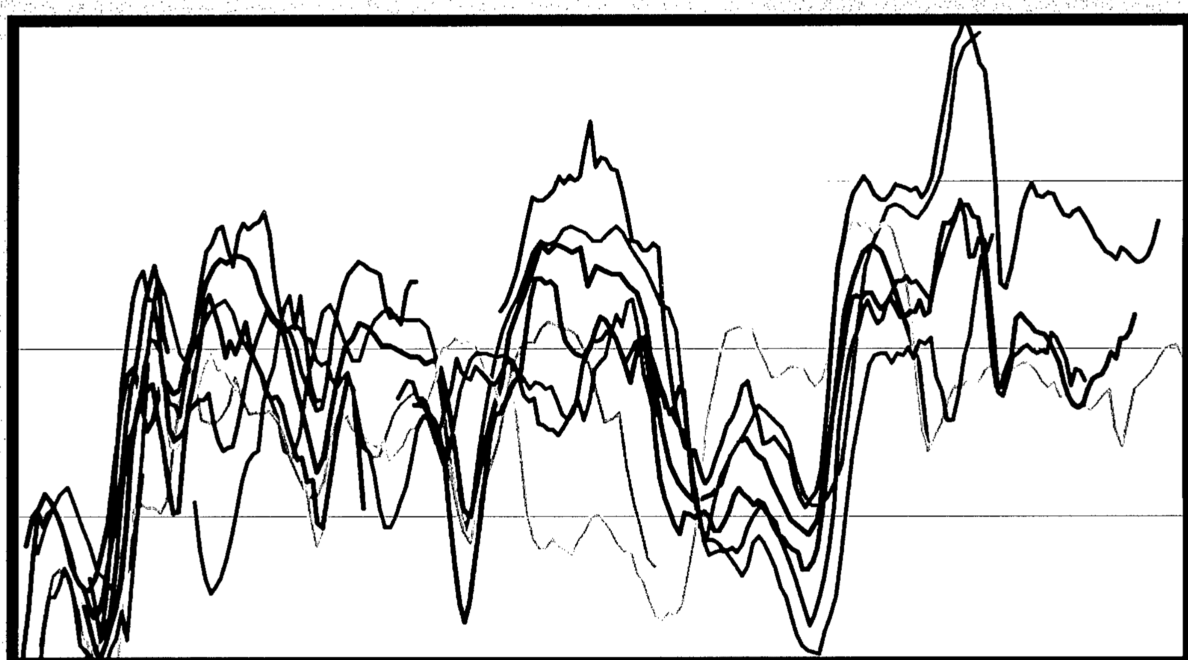
SACLANTCEN REPORT
serial no: SR- 321

SACLANT UNDERSEA RESEARCH CENTRE REPORT



DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

NORTH ATLANTIC TREATY ORGANIZATION   ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD

Piston Coring Capabilities at SACLANTCEN: Minimizing and Assessing Core Disturbance

John C. Osler, Lavinio Gualdesi, Enzo Michelozzi, and Briano Tonarelli

The content of this document pertains to work performed under Project 04-C of the SACLANTCEN Programme of Work. The document has been approved for release by The Director, SACLANTCEN.

Jan L. Spoelstra
Director

intentionally blank page

Piston Coring Capabilities at SACLANTCEN: Minimizing and Assessing Core Disturbance

John C. Osler, Lavinio Gualdesi, Enzo Michelozzi, and Briano Tonarelli

Executive Summary:
Piston and gravity coring are techniques used to collect samples of seabed material. For underwater acoustics applications, it is typical to measure some physical properties of this material, such as sound speed, magnetic susceptibility, density, and grain size distribution. For example, sound speed of surficial sediments is typically required in acoustic propagation modelling, or to validate the results of an acoustic inversion technique that remotely determines the geo-acoustic properties of the sediment. As such, cores are often cited as *ground-truth*. However, it is difficult to collect longer cores with minimal disturbance. There are many variables that can be adjusted when operating a piston corer, such as free-fall height, core liner material, weight, piston friction, rigging, and winch speed. During the Coring Engineering Trial in March 1999, the aforementioned variables were adjusted in a systematic manner in order to determine their relative effects. Multiple cores were collected at an experimental site in the Capraia basin, north of Elba Island, where a robust geo-acoustic model exists. The amount of compression in each core has been estimated by an analysis of magnetic susceptibility data, correlating and aligning nulls in the response. Laboratory measurements of sound speed and bulk density on three of the cores have been compared with each other and with the geo-acoustic model. It has been determined that the critical factors in the operation of the piston corer include the piston design, the piston friction against the liner, the strength of the shear pins, the cable lengths, and the winch speed. Factors that are less significant include the liner material and free-fall height. When properly configured for a given environment, the University of Bologna piston corer (a variant of the SACLANTCEN Sphincter piston corer) can recover cores with only minor disturbance, a compression of approximately 10%.

intentionally blank page

Piston Coring Capabilities at SACLANTCEN: Minimizing and Assessing Core Disturbance

John C. Osler, Lavinio Gualdesi, Enzo Michelozzi, and Briano Tonarelli

Abstract:

Piston and gravity coring are techniques used to collect samples of seabed material. There are many variables that can be adjusted when operating a piston corer, such as free-fall height, core liner material, weight, piston friction, rigging, and winch speed. In order to develop a capability at SACLANTCEN to collect longer cores with minimal disturbance, the aforementioned variables were adjusted in a systematic manner in order to determine their relative effects. During the Coring Engineering Trial in March 1999, multiple cores were collected at an experimental site in the Capraia basin, north of Elba Island, where a geo-acoustic model has been developed based on a time domain inversion of wide-angle reflection data and frequency domain modelling of bottom loss data. The disturbance of the seabed material during the coring process may have an adverse effect on its physical properties, such as sound speed, magnetic susceptibility, and bulk density. Accordingly the amount of compression in each core has been estimated by an analysis of magnetic susceptibility data, correlating and aligning nulls in the response. Laboratory measurements of sound speed and bulk density on three of the cores have been compared with each other and with the geo-acoustic model.

From a seabed dominated by silt and clay material with some thin layers containing shells, the properly configured piston corer was able to recover cores of 5 to 6 m in length with a compression of approximately 10%. When it is not properly configured or does not function properly, the compression may be considerably higher, 25 to 35%. Critical factors in the operation of the piston corer include the piston design, the piston friction against the liner, the strength of the shear pins, the cable lengths, and the winch speed. Factors that are less significant include the liner material and free-fall height. The laboratory measurements of sound speed compare favourably with a geo-acoustic model and qualitatively with a vertical incidence seismic reflection profile. Laboratory measurements of bulk density are higher than those determined for the geo-acoustic model but may be explained, in part, by the compression of the material during coring.

Keywords: Piston coring, surficial sediment, physical properties

Contents

1 Introduction

Piston and gravity coring are techniques used to collect samples of seabed material. For underwater acoustics applications, it is typical to measure some physical properties of this material, such as sound speed, magnetic susceptibility, density, and grain size distribution. These measurements are often compared with the results of an acoustic inversion or other technique for remotely determining the geo-acoustic properties of the sediment. As such, cores are often cited as *ground-truth*. This view is naïve given the likelihood that the material is in some manner disturbed during the collection or subsequent handling. However, core disturbance depends on the implementation of the coring technique and handling procedures and can be minimized. Furthermore, it is possible to make some first order estimated of core disturbance based on field measurements of physical properties.

The objectives of this research were two-fold. First, to develop, or re-gain, a capability at SACLANTCEN to collect longer cores, of 5 to 8 m in length. This is motivated by ongoing research in low frequency active sonar and geo-acoustic inversion using matched field processing that require an understanding of the physical properties of surficial sediments, including physical samples. Second, to assess, and quantify in so far as possible, the core disturbance that results from different corers and their configurations. In particular, for the University of Bologna's version (Busatti *et al.*, 1980) of the *Sphincter* piston corer that was originally developed and used at SACLANTCEN (Kermabon *et al.*, 1966; Kermabon and Matteucci, 1970).

To develop and refine the coring technique, the Coring Engineering Trial (CET) was conducted in March 1999. The performance of the corers was tested for different configurations, including changing the free fall height, core liner type, piston tightness, and cable lengths. Auxiliary instrumentation, namely tilt sensors and load cells, were used to monitor the corers during their deployment, bottom penetration and recovery. Appropriate modifications to the rigging and mode of operation of the piston corer during the CET, led to the collection of cores that were much longer than those recovered during previous attempts at the same location and exhibit minimal compression.

2
Piston Corer Design and Operation

The original SACLANTCEN piston corer (Figs. 1 and 2), called *Sphincter* after its nose mechanism, was composed of: a core head with a vane assembly, a set of removable weights (to yield a maximum mass of 1000 kg); a driving mechanism for the catcher in the nose cutter; a barrel in various sections to fit the required length; a split piston with calibrated hole and shear pins; and a *sphincter* nose (Kermabon *et al.*, 1966).

It was designed following coring principles that are widely accepted and continue to be cited. Hvorslev (1949) defined the ideal coefficients for a nose cutter design that would maximize the *gross recovery ratio* between the gross length of the collected core and the barrel penetration length into the sediment. In particular, he defined three diameter ratios that respectively control the inside friction, the outside friction and the volume of displaced sediment for a good nose cutter. In Table 1, these ratios are presented for the corers developed by SACLANTCEN and various other institutions (*OEG, SW104, SOPROMAR, and BIO*).

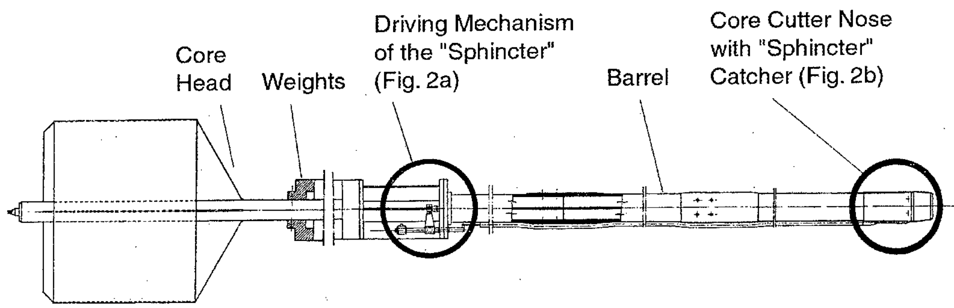


Figure 1 *Schematic drawing of SACLANTCEN Sphincter piston corer*

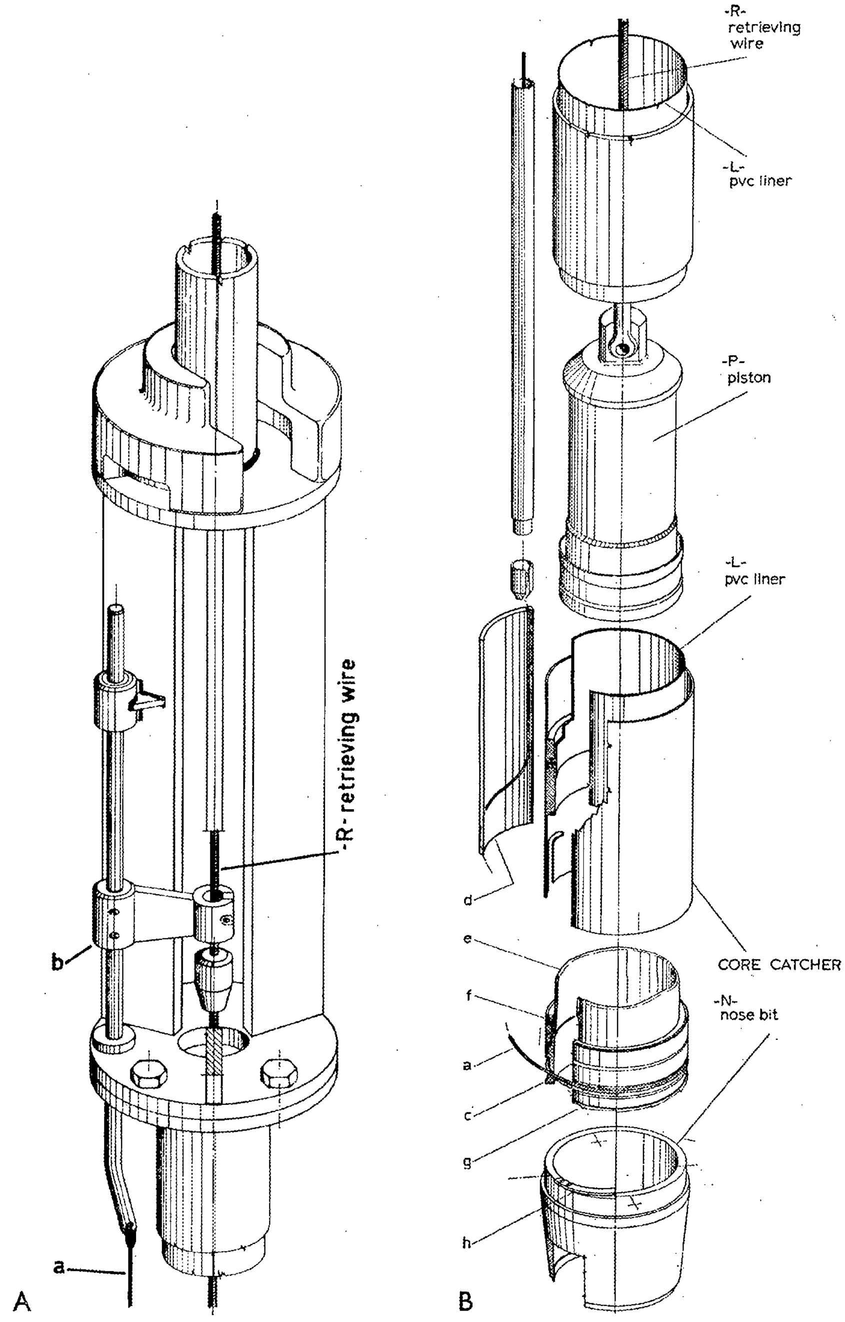


Figure 2 *Schematic drawing of the SACLANTCEN Sphincter corer (a) driving mechanism and retrieving wire and (b) core cutter nose, split piston, liner and retrieving wire.*

Table 1 *Hvorslev's coefficients for gravity and piston corers from various institutes (Parts 1 and 2) and comparison with Hvorslev's empirical limits (Part 3).*

	Reference	SW 104	SOPR-OMAR	BOL (PVC)	BOL (PC)	OEG	BIO
Part One	**Dimensions**						
S = Liner surface (m^2)	0.05	0.03	0.02	0.05	0.04	0.04	0.03
Ds = Liner I.D. (mm)	121.00	104.00	84.00	120.00	113.00	113.00	99.16
De = Nose I.D. (mm)	120.00	104.00	85.00	118.00	118.00	112.00	99.06
Dw = Nose O.D. (mm)	144.00	121.00	115.00	144.00	144.00	146.00	120.65
Dt = Barrel O.D. (mm)	137.00	114.30	105.20	140.00	140.00	142.00	114.30
Part Two	**Hvorslev's Coefficients**						
Ci= Inside friction coefficient	0.83	0.00	-1.18	1.69	-4.24	0.89	0.10
Co= Outside friction coefficient	5.11	5.86	9.32	2.86	2.86	2.82	5.56
Ca= Volume of displaced sediment	44.00	35.36	83.04	48.92	48.92	69.93	48.34
Part Three	**Comparison to Empirical Limits**						
(1-Ci)/1 = Inside friction (Normalized difference)	0.17	1.00	2.18	***-0.69***	5.24	0.11	0.9
(3-Co)/3 = outside friction (Normalized difference)	***-0.70***	***-0.95***	***-2.11***	0.05	0.05	0.06	***-0.85***
(10-Ca)/10 = displaced sediment coefficient (Normalized difference)	***-3.40***	***-2.54***	***-7.30***	***-3.89***	***-3.89***	***-5.99***	***-3.83***

The abbreviations in Table 1 are defined as follows:

REFERENCE — Theoretical design characteristics of the SACLANTCEN *Sphincter* corer described in Kermabon *et al.* (1966) on page 155.

SW104 — CNR BOLOGNA 1.25 m gravity corer (Magagnoli and Mengoli, 1995) purchased by SACLANTCEN and used for sampling the water-sediment interface.

SOPROMAR — CNR BOLOGNA 1200 kg gravity corer (on loan to SACLANTCEN for the CET) equipped with blade nose.

BOL (PVC) — CNR BOLOGNA piston corer (Busatti *et al.*, 1980) on loan to SACLANTCEN for the CET equipped with 4 or 8 m barrel,

polyvinylcarbonate liners, and piston modified during CET to fit both liner types.

BOL (PC) CNR BOLOGNA piston corer (Busatti *et al.*, 1980) on loan to SACLANTCEN for the CET equipped with 4 or 8 m barrel, polycarbonate liners, and piston modified during CET to fit both liner types.

OEG Ocean Engineering Group gravity core is a new modern and more compact version of the above, but used in the CET only as a gravity corer without any piston.

BIO Bedford Institute of Oceanography piston corer with split piston and blade core catcher. Dimensions based on technical drawings (Mr. Bob Murphy, Geological Survey of Canada - Atlantic, Personal Communication).

The concept of first two coefficients (Part 2 of Table 1) is that, in its run into the sediment, the inner and outer diameters of the nose should create *clear zones* with respect to the liner and barrel in order to minimize frictional effects. The specified coefficient limits (1, 3, 10 for the inside friction, outside friction, and volume of displaced material respectively) were established experimentally by Hvorslev (1949) to be effective in improving the gross recovery ratio. The reference corer features are taken from Kermabon *et al.* (1966) and are provided for comparison purposes only. The actual *Sphincter* corer, successively adopted by Research institutions in Bologna, Italy (Busatti *et al.*, 1980), the Italian Navy, and produced by private firms, had slightly different coefficients, since it was difficult to find a continuous supply of commercially manufactured barrels and liners with the desired dimensions.

The third part of Table 1 is a comparison of the coefficients with the empirical limits defined by Hvorslev (1949). Most of the corers respect the limits (values >0) for the first two coefficients or have minor deviations (values <0) while none of the corers respect the limit for the third coefficient. Satisfying the limits, however, only means that when used as gravity corers, that they will collect the maximum length possible, usually never exceeding a gross recovery ratio of 50%. Corer SW104 is an exception as it routinely collects cores with a gross recovery ratio well in excess of 50%. It is closest to satisfying the limit for the area ratio Ca, although it is still not compliant. However, the principal factor explaining the higher gross recovery ratios realized with the SW104 corer is the limited friction on its short barrel when penetrating soft surface sediment. The BOL, BIO, and OEG corers are not compliant with third coefficient limit, but when used as piston corers this is not critical. Although the BOL and OEG piston corers were onboard during the CET, a performance comparison could not be made because only a 4 m barrel was available for the OEG corer.

The BOL (PC) was used intensively and proved to be very effective and reliable as a piston corer. Unfortunately, its overall length of 12 m is not well suited to the deck space and hoisting gear on *R/V Alliance*. Its operation is possible only in very calm seas—a major limitation. Following the CET, a number of modifications were introduced to reduce its overall length and improve its handling on deck. The BOL (PC) core head and weight stand (Fig. 1) were replaced by the OEG corer head (Fig. 3). This head is more rugged, compact and versatile because it holds six 95 kg lead weights and six 30 kg steel

weights in its vane. The total weight including an 8 m barrel can be as much as 1150 kg. This modularity is necessary when penetrating less dense sediments. When completely free from ballast complements, its 400 kg weight becomes a vital feature to avoid excess penetration. It was also noted that the upper end of the BOL (PC) barrel has a restriction due to the connection flange to the core head. The diameter is reduced to 60 mm, compared with the barrel I.D. of 120 mm. It was suspected that this obstruction of the out-coming water flow exerts a counter-pressure to the piston run during the barrel penetration and leads to deformation of the core. For this reason a suitable interface was interposed between barrel and connection flange to restore a full 120 mm diameter out-flow section. During a subsequent trial in May 1999, these modifications did provide for easier handling and did not adversely effect the performance of the corer.

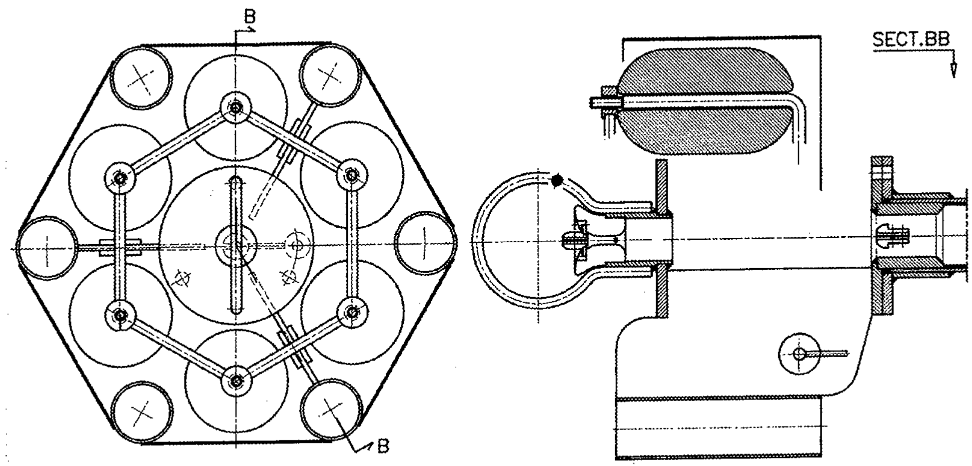


Figure 3 *Drawing of SACLANTCEN OEG Core Head*

3

Coring Locations, Technique Modifications, and Core Recovery

During the CET, cores were collected in two areas, outside of La Spezia harbour (Cores 2-12, Fig. 4) and in the Capraia Basin (Cores 12-33, Fig. 5). Cores 12 to 23 were collected at an experimental site, CS2, where vertical incidence seismic reflection, wide angle seismic reflection, and bottom loss data exist and have been analyzed (Holland and Osler, 1999; Holland *et al.*, 1999). Accordingly, this is the location where the most extensive tests and comparisons have been conducted. In the last day of the CET, cores were collected at some other experimental sites of relevance to analysis of the SCARAB 1997 data set (Cores 24-33, Fig. 5). These sites provided an opportunity to assess whether the piston coring techniques refined in the preceding days were applicable to a broader range of sediment types. In particular, cores 24-26 sampled coarser grained material with more shell material and cores 32-33 sampled a very fine grained homogeneous mud.

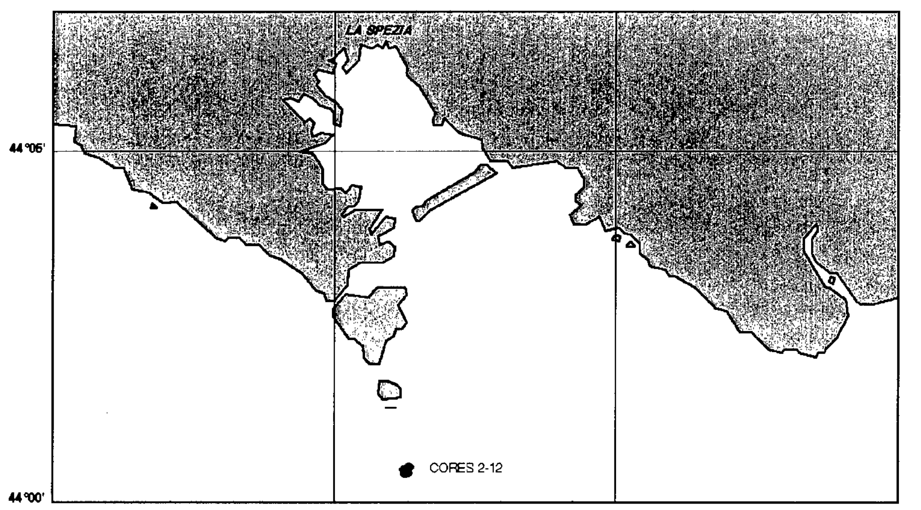


Figure 4 *Locations of cores collected outside La Spezia harbour, 11-13 March, 1999.*

Tables 2 and 3 contain the geographical location, type of coring device and its configuration for each of the cores. In addition, the penetration of the corer and amount of core recovered are used to calculate an apparent percentage compression (1 – gross recovery ratio). The depth of penetration is estimated by visual inspection of the corer—looking for a *mud line*. However, whilst the corer is raised through the water column and maneuvered onto the deck, it can be *washed* so the apparent percentage compression values should only be considered as estimates.

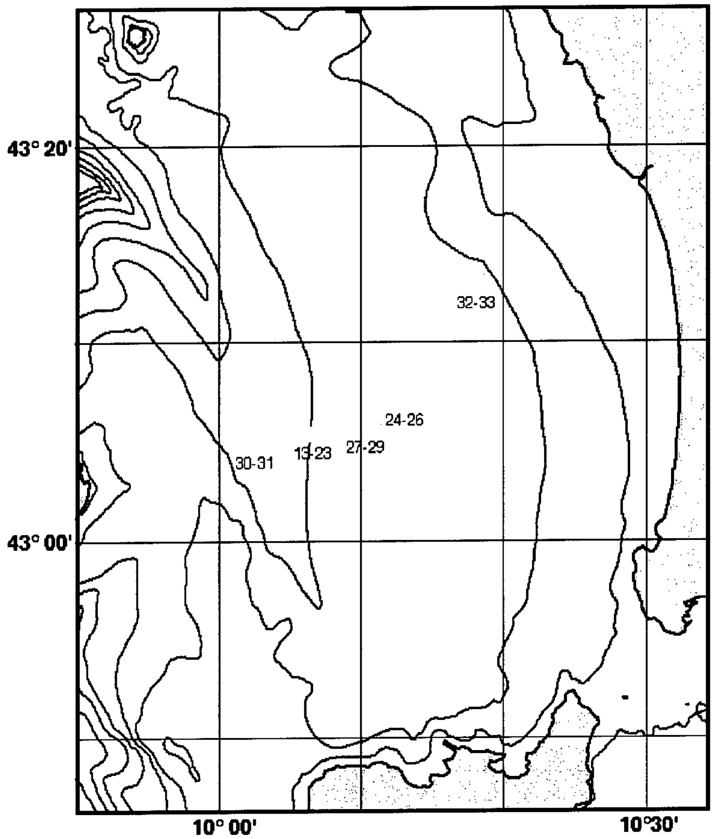


Figure 5 *Locations of cores collected in the Capraia Basin, 14-17 March, 1999*

The extraction load is the peak force measured on a load cell attached to the block over which the cable passes from the winch to the corer. Assuming that the cable from the load cell to the block is at an angle of 45°, the vertical and horizontal components are equal and 71% of the total listed in Table 3. Higher values may be caused by at least three factors: deeper penetration into the seabed, stiffer seabed material, or a horizontal offset between the corer and the winch (a wire angle). For the piston cores at Site CS2 (16, 17, 20, 21, 22, and 23), extraction loads in the range 1350 to 1550 were observed with the exception of Core 16 that had less penetration and recovery. The highest extraction load observed during the trial was at site CS5 (Core 33), 1200 kg more than the mass of the empty corer (1000 kg), presumably due to the full 8 m penetration of the core barrel and the 6.15 m of core recovered. In addition, weather conditions were deteriorating so the wire angle may have also been a contributing factor.

Two core liner materials were used: opaque polyvinylcarbonate (PVC) of the standard variety that is used for plumbing applications; and transparent polycarbonate (PC). Advantages of the PVC include its low cost, widespread availability, and its relatively uniform diameter. The principal disadvantage is that it is not possible to make a visual inspection of the material, core disturbance, and in the case of a piston core, the position of the piston relative to water-sediment interface. The PVC is also more flexible than the PC so care must be taken not to bend the core liners in handling, transportation and

storage. Cores 20 and 21 were collected with the identical rigging of the piston corer, but using different types of liner. The amount of core recovered was similar though Core 21 had a higher apparent compression. A further comparison between these cores, based on the physical property measurements, is presented in Section 5.

Three free-fall heights were tested, 1.7, 2.5 and 3.5 m, Cores 23, 22, and 20 respectively, while keeping other variables fixed. The terminal velocity of a corer is typically reached in 2.15 m (7 feet). The reference free fall height was 2.5 m (using Core 20 is a reference for the tests at CS2). The shorter free-fall height (1.7 m) resulted in less material recovered in the core, while the larger free-fall resulted in only a marginal increase in the amount of core recovered. A further comparison between these cores, based on the physical property measurements, is presented in Section 5.

At Site CS2, gravity cores were collected with two types of corers: the SW104 to compare with the effects of the piston corer on the upper 1 m of sediment, and the (SOPROMAR) gravity corer for a similar comparison with the upper 6 m. The SW104 is well designed (following Table 1) to obtain cores with minimal disturbance and past experience suggests that this is the case. With the number of additional weights adjusted accordingly, it is usually possible to retain a relatively undisturbed water-sediment interface. The SOPROMAR corer was used in two modes, free falling into the seabed (Core 14) and winched at approximately 1 m/s (Core 15). The two methods recovered similar amounts of core, though the core catcher did not close properly for core 15, so the amount of core recovered should have been higher. A further comparison between the gravity and piston cores, based on the physical property measurements, is presented in Section 5.

The core cutting, capping and storage procedure varied between the piston and gravity cores. Due to their length, the BOL, SOPRAMAR and OEG corers had to be laid horizontal to remove the core liner from the barrel, while the SW104 could remain vertical. After removal form the core barrel, the BOL piston core liners were returned to the vertical and cut. An initial cut was made against the piston, above the seals, to allow the piston to be grasped, followed by a second cut below the piston to relieve the vacuum. With the piston removed, water above the sediment was siphoned (and retained) to allow a foam bulkhead to be placed at the top of the sediment. A third and final cut was made such that approximately 50 cm of water could be returned to the core above the bulkhead to serve as a bottom water sample for sound speed measurements. With bulkheads in place, the piston cores were stored and analyzed in the horizontal. The horizontal storage procedure was selected in order to avoid cutting the piston cores into shorter sections (< 2 m) and the associated loss of physical property measurements. (Measurements of sound speed and magnetic susceptibility cannot be made within approximately 0.15 and 0.20 m respectively of the end of a section of core). Bulkheads were also placed in the gravity cores from the SOPRAMAR and SW104 to allow horizontal storage and analysis of these cores. However, their shorter lengths, a maximum of 1.25 m for the SW104, was compatible with existing methods for storage and analysis. Several recommendations concerning improved core cutting, handling and storage are described in Section 6.

Table 2 *General information concerning cores obtained during the CET. OEG=Ocean Engineering Group corer (rigged as a gravity corer with 4 m barrel), BOL 4 (or 8)=University of Bologna Sphincter piston corer with 4 or 8 m barrel, SW104=University of Bologna 1.25 m gravity corer, Mini=SACLANTCEN Mini corer. CS 1, 2, 2E, 2W, and 5 are location names used in the SCARAB 97 sea-trials (Holland and Osler, 1999).*

#	Date	Time (UTC)	Depth (m)	Site	Latit-ude	Longitud e	Core Type	Mass (kg)	Liner Type
1	11-Mar-99						OEG	1000	PC
2	11-Mar-99	15:26:03	24.7	La Spezia	44.0081	9.8554	OEG	1000	PC
3	11-Mar-99	16:01:04	25.0	La Spezia	44.0066	9.8553	OEG	1000	PC
4	12-Mar-99	9:57:49		La Spezia	44.0066	9.8550	OEG	700	PC
5	12-Mar-99	13:26:12	24.9	La Spezia	44.0063	9.8545	BOL 4	710	PVC
6	12-Mar-99	16:23:32	25.0	La Spezia	44.0066	9.8545	BOL 4	710	PC
7	12-Mar-99	20:12:32	25.0	La Spezia	44.0066	9.8544	SW 104	175	PVC
8	12-Mar-99	20:34:00		La Spezia	44.0066	9.8544	SW 104	175	PVC
9	13-Mar-99	13:09:16	25.0	La Spezia	44.0075	9.8542	BOL 4	710	PC
10	13-Mar-99	15:04:23	25.1	La Spezia	44.0075	9.8543	Sopromar	800	PVC
11	13-Mar-99	15:32:06	25.0	La Spezia	44.0076	9.8543	Sopromar	800	PVC
12	13-Mar-99	16:32:03	24.9	La Spezia	44.0076	9.8543	SW 104	175	PVC
13	14-Mar-99	7:34:45		CS 2	43.0864	10.1108	Mini	88	PC
14	14-Mar-99	8:23:12	150.4	CS 2	43.0920	10.1109	Sopromar	800	PVC
15	14-Mar-99	8:59:15	150.0	CS 2	43.0874	10.1114	Sopromar	800	PVC
16	14-Mar-99	12:15:58		CS 2	43.0868	10.1113	BOL 4	710	PC
17	14-Mar-99	15:45:03	150.0	CS 2	43.0867	10.1117	BOL 8	800	PC
18	14-Mar-99	18:16:39	150.5	CS 2	43.0865	10.1105	SW 104	110	PVC
19	14-Mar-99	19:44	150.3	CS 2	43.0874	10.1111	SW 104	110	PVC
20	15-Mar-99	9:58:18	150.4	CS 2	43.0880	10.1104	BOL 8	800	PC
21	15-Mar-99	15:04:57	150.1	CS 2	43.0864	10.1112	BOL 8	800	PVC
22	15-Mar-99	16:31:45		CS 2	43.0870	10.1108	BOL 8	800	PC
23	16-Mar-99	9:36:13	150.3	CS 2	43.0868	10.1109	BOL 8	800	PC
24	16-Mar-99	12:48:02	122.5	CS 1	43.1005	10.1866	Mini	88	PC
25	16-Mar-99	13:14:46	127.5	CS 1	43.1010	10.1866	BOL 8	800	PC
26	16-Mar-99	14:12:41	127.7	CS 1	43.1010	10.1861	SW 104	105	PVC
27	17-Mar-99	5:41:47	131.0	CS 2E	43.0917	10.1570	BOL 8	800	PC
28	17-Mar-99	6:21:09	130.6	CS 2E	43.0936	10.1581	SW 104	105	PVC
29	17-Mar-99	6:45:38	131.0	CS 2E	43.0915	10.1568	SW 104	105	PVC
30	17-Mar-99	7:40:06	166.2	CS 2W	43.0798	10.0532	SW 104	105	PVC
31	17-Mar-99	8:10:14	166.5	CS 2W	43.0790	10.0535	BOL 8	1000	PC
32	17-Mar-99	9:45:24	102.5	CS 5	43.2199	10.3090	SW 104	105	PVC
33	17-Mar-99	10:11:36		CS 5	43.2197	10.3061	BOL 8	1000	PC

Table 3 *Further details and comments concerning the CET cores. Locations and corer devices are listed in Table 2. The apparent compression is the difference between the amount of core recovered and the estimated penetration of the corer, expressed in percent. The length of the core nose, 35 cm for the SACLANTCEN sphincter piston corer and 10 cm for the SW104 is added to the length of core recovered before calculating the apparent compression.*

#	Penet-ration (m)	Reco-very(m)	Appar. Comp-ression (%)	Extr-action Load (kg)	Free Fall (m)	Comments
1	3.8	1.98	39	1500	4.3	
2	4	2	41	1600	4.4	
3	3.5	1.8	39	1300	5.4	
4	2.05	0.85	41	1100	4.4	
5	3.84	2.52	25	1350	2.5	
6	3.8	0.5	78	1350	2.5	Test of the white plastic piston. It jammed and the piston split too early. Subsequent piston cores all used the metallic piston, machined to fit in the PC liner.
7	0	0	N/A	N/A	4.7	Corer fell over 2 sec after impact.
8	0	0	N/A	N/A	3	Corer fell over gradually after impact.
9	3.84	2.95	14	1150	2.5	
10	0	0	N/A	N/A	Winch 1 m/s	Corer fell over after impact.
11	5.2	3.05	35	N/A	2.7	Mud was washed from side of core barrel during recovery, penetration difficult to estimate.
12	0.4	0.4	-25	N/A	3	Corer fell over.
13	1.1	0.65		N/A	3	
14	6.8	3.18	50	1400	3.4	
15	6.8	3.53	45	1400	Winch 0.9 m/s	Core catcher did not close properly, approximately 30 cm of material was hanging out below catcher.
16	5.38	2.63	48	1200	2.5	1) Test of the counterweight showed a penetration to 35 cm. 2) Piston did not split.
17	7.06	4.85	28	1550	2.5	Additional seawater was added to the bottom water in the core.
18	0.8	0.4	11	250	Winch 1 m/s	Sample disposed
19	1.25	1.22	-6	350	8	
20	6.56	5.55	11	1450	2.5	1) Tried making the piston tighter in the liner. 2) Core cutter became blocked and acted as a spear.
21	7	5.48	18	1350	2.5	PVC liner has a 6 mm larger diameter than the PC.
22	6.8	5.68	12	1450	3.5	Tried adding 1 m to the free fall.
23	6.45	4.85	20	1400	1.7	Tried reducing free fall by 0.8 m.
24	1.3	0.6	54			Confirmed seabed is soft and safe to proceed.
25	4.1	3.6	4	1550	2.5	

26	1.15	0.9	13		3.2	
27	5.9	4.4	19	1650	2.5	Coral fragments in cutter, sandy material at top of core.
28	1.34	0	N/A		3	Strings to control the core catcher were ripped by shells.
29	1.3	1.11	7		3	
30	1.35	1.3	-4		3	No water left above sample, core liner full.
31	7.45	4.37	37	1700	2.5	1) Sphincter was about 50% closed. We may have lost some core, explaining why there was so much water between piston and sediment (1.4 m). It is not clear whether it entered at the joint, passed the piston from above, or travelled the length of the core from the base. 2) Nose was full of shell fragments, but bottom of core is a very uniform clay/silt
32	>1.6	1.35	N/A		3	Corer penetrated beyond tail fins, impossible to determine position relative to seabed.
33	8	6.15	19	2200	2.5	1) 2nd snap on block not observed, expect that piston travelled almost full length of barrel before splitting (it was found within 0.5 m of top) and that corer descent was stopped by the piston. 2) Stiff and relatively dry clay at base of core, some shells in the nose.

4

Physical Property Measurements

Physical property measurements of the cores included magnetic susceptibility, compressional wave sound speed, and laboratory analysis of dry and wet density, porosity, and grain size (only where coarser material was encountered). The first two physical property measurements were made on board *R/V Alliance*, while the latter were conducted at SACLANTCEN. The on board measurements were made as soon as possible following the collection of the cores. However, given the large volume of core recovered, the sound speed measurements required approximately three weeks to complete.

Magnetic susceptibility measurements were made using a Bartington Instruments Ltd. core scanning sensor MS2C (ϕ135) with a sensitivity of 10^{-6} CGS. Measured values were corrected for the relative response due to varying core diameter. Unfortunately, it was necessary to extrapolate beyond the manufacturer's calibration curve which is only defined for core/sensor coil diameter ratios (d/D) up to 0.75. Correction factors of 0.72, 1.2, 1.4, and 1.58 were used for d/D ratios of 0.58 (SOPROMAR), 0.73 (SW104), 0.79 (BOL PC), and 0.84 (BOL PVC). Intervals of core with nulls in the magnetic susceptibility may have several origins. They may represent intervals in which there was no deposition of magnetic materials, material with a higher porosity such as sand, or areas where the core may be disturbed (cracked).

Compressional wave sound speed measurements were made using a system designed at SACLANTCEN. Travel times between transmitting and receiving transducers are based on a peak in the cross correlation between a replica of the frequency shift keyed (FSK) pulse and the received signal. The measurements are typically made at 200 kHz, supplemented by measurements at 50 kHz when the received levels at 200 kHz are too weak due to attenuation or scattering, usually in sandy and shelly material. The measured travel times are then corrected to *in situ* sound speeds. This requires travel times for a distilled water reference (a piece of core liner of identical diameter), and the temperatures of the core, the reference sample, and the in situ bottom water. For the cores collected in the Capraia basin, the bottom water conditions were taken from CTD measurements made at the same locations in January 1999. At these depths, it is reasonable to assume that the water masses properties did not change significantly in the two month interval between the CTD measurements and the collection of the cores (Jurgen Sellschopp, Personal Communication).

Laboratory analysis follows the standard SACLANTCEN methodology described in Kermabon *et al.* (1968). Samples of approximately 10 g are removed from the core by drilling a hole in the liner and using a piston syringe for extraction. From the weight measurements before and after the sample is dried, bulk and grain density, porosity, and water content may be calculated.

5
Analysis

5.1 Magnetic Susceptibility

A comparison of magnetic susceptibility measurements for Cores 13-23 (Fig. 6), collected at CS2, provides a means for assessing the different coring techniques. Nulls in magnetic susceptibility are more pronounced and reliable than peaks and their alignment is the basis of the analysis technique. A simple three-parameter model is applied, including a depth offset to account for material missing at the top of the core, and two values of compression, one at the top of the core and another at the base. A linear interpolation is applied to all intermediate depths. Compression values are determined such that the nulls in the susceptibility curves are aligned to the reference curves (Fig. 7) and the measured core lengths are restored to the depth of penetration of the corer, less the length of the core cutter nose. Note that the extent to which the sediment in the core is actually being compressed is unclear. Compression would require a porosity decrease and an associated water flow that is unlikely given the relatively low permeability of fine grained sediments and the brief period in which the core barrel penetrates the seabed (Kate Moran, Personal Communication). An alternative is to consider the apparent compression as the percentage of material in front of the descending core barrel that was not able to enter.

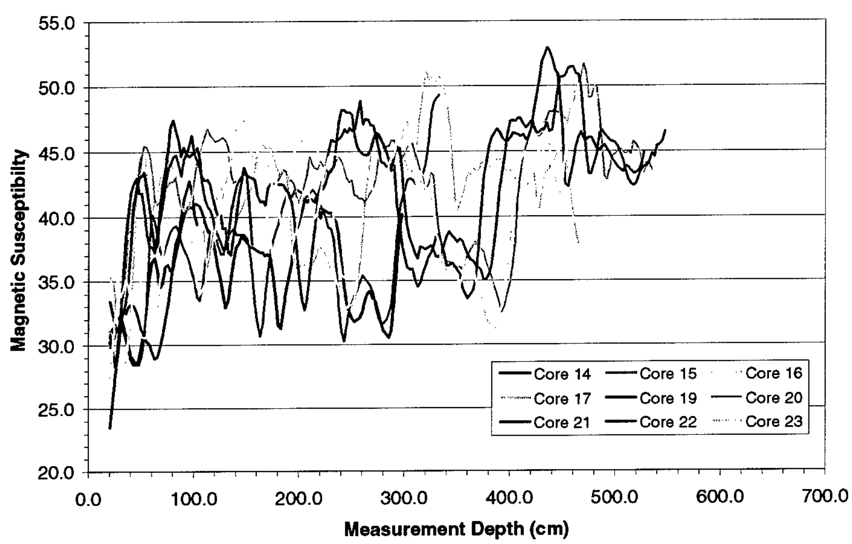


Figure 6 *Magnetic susceptibility versus depth as measured on cores collected at CS2.*

Core 19 was selected as a reference for the top 1 m (Fig. 7). It was collected with the SW104 corer. It is assumed to include the water sediment interface and to have no compression. This is a reasonable assumption as the length of core recovered was just less than the apparent penetration of the corer (and slightly more after correcting for the length of the nose). Fortuitously, Core 19 has a peak in magnetic susceptibility (attributable to anthropogenic activity of the Etruscans) followed by a distinct null and then a strong gradient (Fig. 7). This was very helpful for determining the depth offset of the longer cores. Core 21 was selected as a reference for the deeper cores, in part because of it remarkable similarity to Core 22 (Fig. 7). The depth offset and compression (assumed to be uniform) were selected to match the magnetic susceptibility of Core 19 and to yield a restored depth equal to the apparent depth of penetration (Table 4). Core 22 served as an auxiliary reference in the data gap in Core 21 caused by the core section boundary.

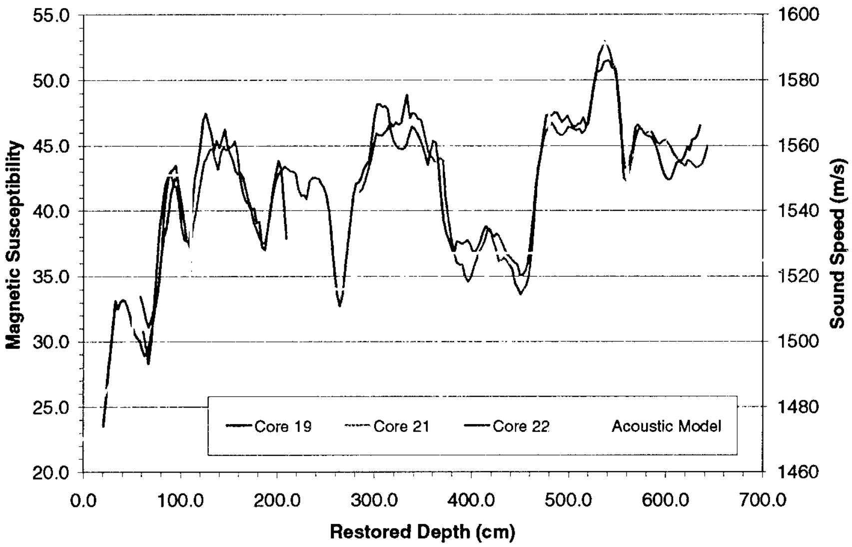


Figure 7 *Magnetic susceptibility versus depth after being restored using the compression functions in Fig. 8. Cores 19, 21, and 22 serve as reference curves for determining the compression behaviour of the remaining cores. The magnetic susceptibility curves are also compared with a geo-acoustic model for Site CS2 based on the analysis on wide-angle seismic reflection and bottom loss experiments (Holland and Osler, 1999).*

Compression values for all the cores, determined relative to the reference curves are displayed in Fig. 8 and summarized in Table 4. The magnetic susceptibility values plotted versus the restored depth using these compression functions are displayed in Fig. 9. Note that all magnetic susceptibility measurements within 20 cm of the end of a section of core are not displayed to avoid measurements that may include artifacts. The nulls at 70 and 460 cm restored depth are well aligned for almost all of the cores. The nulls at 105, 185, and 270 cm restored depth cm are also well aligned, though they are not present in all the cores, notably Cores 20, and 23. Their absence may be indicative of some variability in the environment. Core 17 and to a lesser extent, Core 23, did not readily submit to this analysis technique. As most of Core 17 can be aligned if a large depth offset is specified, it is speculated that the liner was temporarily blocked after

piercing the first shelly layer at 75 cm restored depth and then resumed sampling material at approximately 300 cm restored depth.

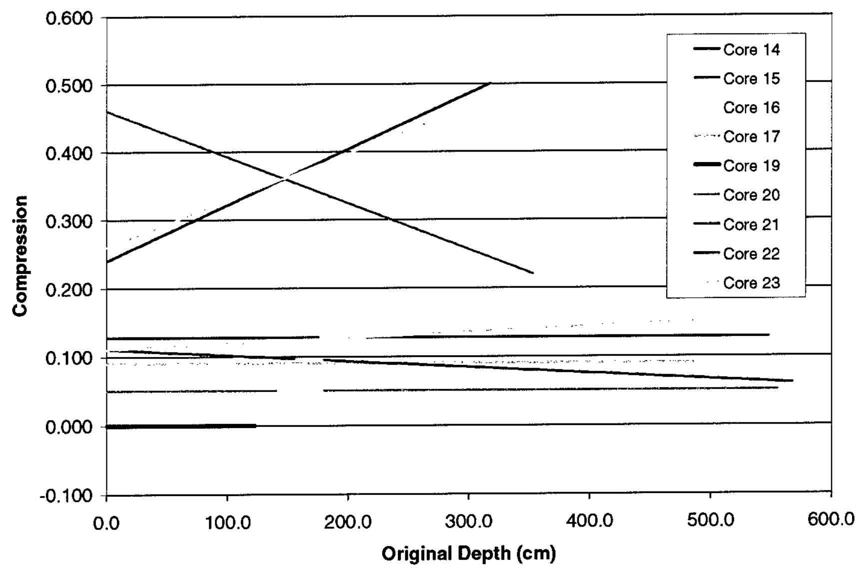


Figure 8 *Compression as a function of depth for cores collected at CS2.*

Although the magnetic susceptibility measurements do not necessarily reflect geo-acoustic properties, a comparison may be useful as an independent means of verifying the restored depth scale. In Fig. 7, the reference magnetic susceptibility curves are compared with a geo-acoustic model for Site CS2, obtained by an acoustic inversion and analysis of wide-angle reflection and bottom loss data (Holland and Osler, 1999). The most prevalent boundaries in the acoustic model (50 and 480 cm) relate to the most prevalent and consistently observed boundaries in the magnetic susceptibility of the cores (70 and 460 cm). While the depths do not correspond exactly, it should be noted that the maximum spatial resolution that can be achieved with the EG&G boomer used in the wide-angle reflection experiments is approximately 0.6 m (pulse length of approximately 0.4 ms). Several cores also have nulls in the magnetic susceptibility in the depth interval from 100 to 400 cm (Fig. 9). However, these nulls are not as consistently observed, perhaps indicative of some variability in the environment. Indeed, the wide-angle reflection/bottom loss analysis will tend to average the geo-acoustic properties over the spatial aperture of the measurement (~1000 m), such that layers that are spatially intermittent may not be manifest in the geo-acoustic model.

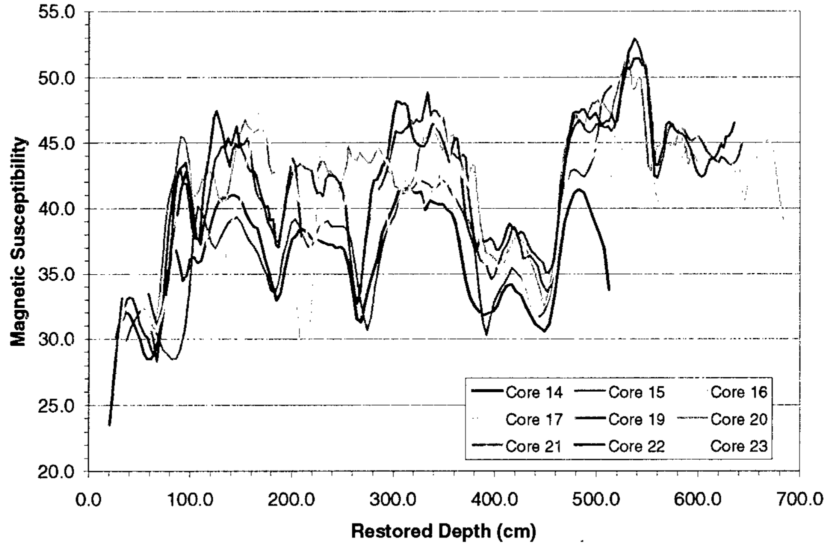


Figure 9 *Magnetic susceptibility versus depth after being restored using the compression functions in Fig. 8.*

Table 4 *Comparison of estimated compression in cores collected at Capraia SCARAB Site 2. G6-SOPROMAR 6 m Gravity Core, G1=SW104 1 m Gravity Core, P4=BOL 4 m Piston Core, P8=BOL 8 m Piston Cor. Length of core cutter nose: 10 cm for G1, 35 cm for P4, P8, and G6.*

Core	Type	Penetration (cm)	Recovered Length (cm)	Apparent Compr. (%)	Model Compr. Top (%)	Model Compr. Bottom (%)	Depth Offset (cm)	Restored Depth + Core Cutter (cm)	Residual= Penetrat.-Restored (cm)
14	G6	680	318	50	24	50	0	547	159
15	G6	680	353	45	46	22	0	574	106
16	P4	538	263	48	30	36	6	448	90
17	P8	706	485	28	9	9	175	729	-37
19	G1	125	122	-6	0	0	0	123	3
20	P8	656	555	11	5	5	35	654	2
21	P8	700	548	18	13	13	38	700	0
22	P8	680	568	12	11	6	36	691	-11
23	P8	645	485	20	11	5	5	598	47

5.2 Bulk Density

Laboratory measurements of bulk density were made on Cores 19, 21, and 22 following the procedure described in Section 4. Sample locations were determined based on an examination of the sound speed profiles, such that material from distinct sedimentary

features would be selected. In Fig. 10, the bulk density measurements are plotted versus restored depth (determined as per Section 5.1). A geo-acoustic model for Site CS2, based on a time domain inversion of wide-angle reflection data and frequency domain modelling of bottom loss data (Holland and Osler, 1999) is also displayed. Several observations can be made. First, the measurements of bulk density values in Cores 21 (PVC) and 22 (PC) are generally similar. Second, the peaks in density correspond to the peaks in sound speed at 75 and 540 cm restored depth. Interestingly, the peak in bulk density at 330 cm is manifest as a significant reflector in the seismic reflection profile, but only a minor increase in sound speed is measured on the cores. The measured values of bulk density are high when compared to the values determined for the geo-acoustic model and also high when they are compared to standard empirical relationships (Hamilton, 1980). The high values for bulk density may result from compression during the coring operation, inadvertent compression or drying of the sample during the laboratory sampling and analysis, or may be intrinsic to the nature of the material. To consider the possibility that the bulk density was modified during the coring operation, *corrected* values of bulk densities are also plotted in Fig. 10, making the assumption that the core compression can be related directly to a decrease in porosity. The *corrected* values are closer to those that resulted from the modelling, though a new discrepancy between Cores 21 and 22 is introduced. This arises because Core 21 has a uniform compression as a function of depth whereas the compression in Core 22 decreases as a function of depth (Table 4), leading to a smaller correction applied at the base of Core 22 than at the base of Core 21.

5.3 Sound Speed

Laboratory measurements of sound speed were made on Cores 19, 21, and 22 following the procedure described in Section 4, using the distilled water reference technique. In Fig. 10, the sound speed measurements are plotted versus restored depth along with the geo-acoustic model for Site CS2 (Holland and Osler, 1999). The consistency between Cores 21 and 22 and the agreement with the geo-acoustic model is remarkable. Two layers with higher velocity are observed between 50 and 100 cm and between 520 and 560 cm. Upon splitting the cores, it was found that these layers contain many shells and shell fragments and some coarser grained sediment. As the attenuation and/ or scattering of the 200 kHz transmissions was appreciable in these intervals, sound speed was also measured at 50 kHz (though this frequency may also be contaminated by scattering). Most significant changes in sound speed correlate with reflectors in the seismic reflection profile for the upper 6 m on a track passing north-south through Site CS2 (Fig. 10). One exception is the shell layer centred at 550 cm, though this may be due to the limited penetration of higher frequency energy at this depth. The cumulative bottom loss analysis in Holland and Osler (1999) revealed, for frequencies in excess of 2000 Hz, that almost all the loss occurred in the upper four metres of sediment.

The sound speed measurements for Core 19 in the upper 40 cm seem to be unreasonably low and should be treated with caution. Further, they are also lower than sound speed measurements made on SW104 cores collected at the same location during SCARAB97 (Holland *et al.*, 1999). As there was no obvious disturbance of the material, an artifact in the sound speed analysis, such as a multi-path arrival, is suspected.

No attempt was made to correct the sound speed measurements for compression, since it is not apparent how the compression influences the bulk modulus. However, it seems reasonable to assume that compression increases both the bulk modulus and density. As sound speed is a function of the ratio between bulk modulus and density, the effects of compression might be expected to be less on sound speed than on density alone.

5.4 Assessment of Core Disturbance

When the piston corer is in an optimal configuration for a given environment, compressions on the order of 10% can be anticipated (Cores 20 to 23). When it is not configured properly (Core 16), the compression may be 25 to 35%, perhaps even higher. In core 16, for example, the piston was too loose and it did not split. It behaved as a poorly designed gravity corer with the piston impeding the escape of water above the water-sediment interface. Long gravity cores collected with the SOPROMAR corer (Cores 14 and 15) have a significant amount of compression, 22 to 50%. In addition, the residual for Core 14 in Table 1 suggests that when the core was configured to free-fall into the bottom, no material was entering the core barrel during the last 1.5 m of penetration—the descending corer began acting more like a spear. Core 15, winched into the bottom at 1m/s, is also missing material at the base of the core, but much of this probably due to incorrect closure of the core catcher.

The piston core is routinely missing material from the top of the core, as much as 0.35 to 0.4 m of material. However, this is characteristic of piston cores as the water in advance of the piston displaces sediments at the water-sediment interface. The BOL piston corer is performing as well as, if not better than, many other corers in that regard. The type of core liner does not appear to be particularly significant. Given the similarity in sound speed and bulk density measurements between Core 21 (PVC) and Core 22 (PC), it would appear that the liner material did not adversely affect the collection of the cores or the sound speed measurements.

Conventional wisdom is that the free fall height should be between 1.55 and 4.6 m (5 to 15 feet). Terminal velocity of a corer is typically reached in 2.15 m (7 feet). During the CET, the reference free fall height was 2.5 m (Core 20 at CS2), other free-fall heights were tested while holding other variables constant. A shorter free fall height (1.7 m, core 23) may help to reduce the amount of material that is missing at the top of a core, however, this is at the expense of not sampling material deeper in the sediment column. (Compare the depth offset and restored depth of Core 23 with Cores 20 and 21, 2.5 m free fall). A larger free fall gave a slightly better penetration and recovery (6.8 m penetration and 5.7 m recovery, both 0.25 m longer than Core 20) with a minor increase in compression.

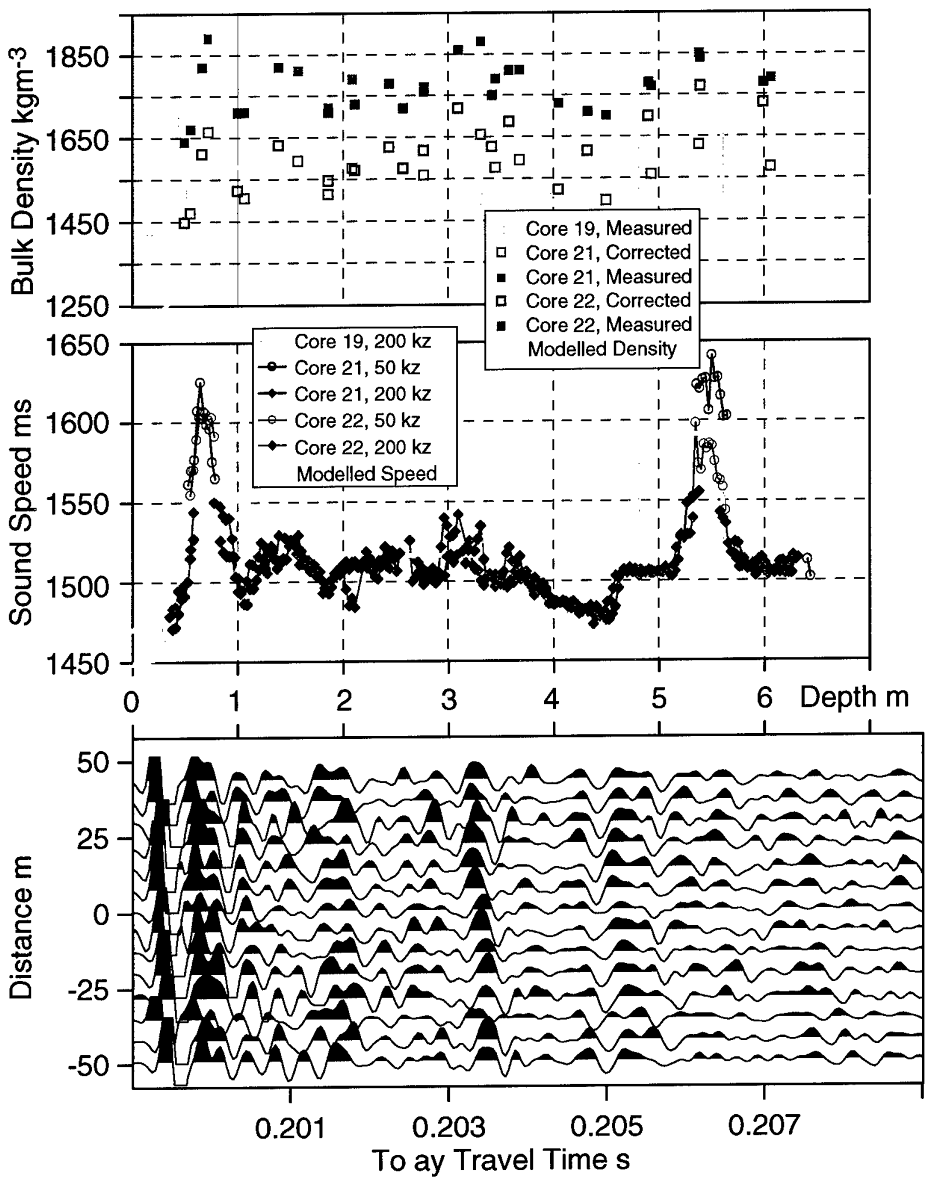


Figure 10 *Top: laboratory measurements of bulk density on Cores 19, 21 and 22 are plotted versus the restored depth. Solid squares are bulk density as measured and open squares are the values corrected for compression. Middle: laboratory measurements of sound speed on Cores 19, 21, and 22 (green, magenta and blue respectively) at 200 kHz (solid diamonds) and 50 kHz (open circles). Density and sound speed measurements are compared to a geo-acoustic model for Site CS2 based on the analysis on wide angle seismic reflection and bottom loss experiments (Holland and Osler, 1999). Bottom: seismic reflection profile passing through Site CS2 using the EG&G Uniboom.*

6
Lessons Learnt and Recommendations

The following comments pertain to use of the BOL (PC) unless stated otherwise.

6.1 Cable Lengths and Winch Speed

It is crucial that the cable lengths be measured accurately and adjusted such that the piston face is at the water-sediment interface at the time when the winch cable tightens after the free fall. Measurements should include: the penetration of the counter weight into the seabed (tested by lowering it to the seabed with a cloth wrapped around it); the vertical excursion of the pelican hook torque arm when it releases the corer; and the rebound of the winch cable. The latter is difficult to estimate, though 1 m gave satisfactory results.

The winch speed should be reduced as the corer approaches the seabed and the winch stopped immediately after the piston core is released. If more cable is let out during the free fall/penetration of the piston core, it will effectively change the accurate cable measurements. It is noted that vertical motion of the research vessel will have a similar effect, causing the piston to pull too early or too late.

6.2 Piston Design and Adjustment

The use of a split piston is generally considered to be essential. When the sediment consistency prevents a full barrel penetration, the maximum core length, although not compressed, is considerably shorter than the ones collected with the same weight in a less dense sediment. This means that the corer is in equilibrium and the piston has finished its function. Unfortunately, to recover the corer it is necessary to reel in the cable requiring the piston, attached to the cable (Fig. 3), to travel to the top of the core barrel. If the piston does not split, the piston travel inside the liner would create a vacuum effect, destroying the core and sometimes even imploding the liner and barrel. Ideally, there would be no requirement for a split piston if one were able to equip the corer with a suitable load for the soil consistency. In practice, this is difficult to achieve due to the variability of the soil layers and the loading limits of the deployment gear. Moreover, an evaluation of the corer loading versus soil rigidity cannot be made until some cores have suffered the aforementioned negative effects. When a solid piston is being used, if it is too tight, the core liner will either shatter or be deformed (as observed in Rapid Response 1998). If it is too loose then, as with the split piston, it will have little beneficial effect and may even cause the corer to effectively behave as a poorly designed gravity corer in which the escape of the water above the incoming sediment is impeded by the piston.

To control the splitting of the piston, the shear forces of the pair of calibrated pins must be known and predictable. In laboratory tests, pins of the same diameter and material were sheared. A shear force of 1850 N was consistently measured for brass pins. For a very long piston travel and a very hard bottom (a situation to be avoided), it is estimated that the shear pins must have a shear force in excess of 1400 N. Below this value, there is a risk that the piston can split too early for a core that would otherwise have had a good gross recovery ratio.

The piston friction within the liner plays an important role in achieving a good gross recovery ratio and long core length. If the piston is too tight, the piston will split too early and prevent the collection of any more material. If it is too loose, water from above the piston may pass the o-ring seals thereby reducing the force it applies and its effectiveness. There are a couple of anecdotal measurements of the appropriate tightness of the piston. First, it should not move in the liner by the force of gravity alone. Second, in a recovered core, it should be impossible to move the piston until a hole is drilled below the piston to relieve the vacuum. Note that there are usually are a few tens of centimeters of water between the piston and the top of the sediment—a *perfect* core would have 35 cm, the length of the core nose cutter. Third, if it the piston never splits, then it is too loose.

To quantify the piston friction that gave good results during the CET, the force required to move the piston through the core liner was measured. A 1.5 m portion of PC liner was assembled in a vertical orientation with one end connected to the deck. A standard piston was inserted in the liner and then the liner was filled with water above the piston. The upper part of the piston was tied to a robust string controlled by the winch. A direct readout dynamometer measured the force required to move the piston. Two kinds of measurements were made. In the first case, the system loading was progressive, but fast. In the second case, an impulsive loading was applied. The first case may be representative of the load applied during recovery of the corer from the seabed while the latter may be representative of its penetration. The average measurements were 500 N and 1000 N for the progressive and impulsive loading respectively. These measurements provide target values for adjusting the piston friction if SACLANTCEN is faced with a new piston design or the more likely scenario of having to use core liner or piston gaskets from a different commercial manufacturer.

GSC-Atlantic has a piston design that allows the seals to be tightened against the liner (Bob Murphy, Personal Communication). While this allows for more adjustment, especially if there is variability between different lots of core liners, it also introduces another component that can be set incorrectly. To a certain extent, the piston used in the BOL piston corer can also be adjusted by tightening the plates that keep the seals in place. On one occasion during the CET, the seal was adjusted by wedging black electrical tape between the piston disc and the seal (Core 20), although no significant improvement was noticed.

One of the pistons available at SACLANTCEN (white plastic assembly) does not function properly because the disc separating the two seals on the piston is too short and allows some rotational motion of the piston. If it rotates, it becomes wedged in the liner. After discovering this problem (Core 6), the BOL metallic piston was machined in order that it could be used in PC and PVC liners (originally the metallic piston only fit in the PVC liner). There are two sets of seals that can be used with the piston, the larger ones fit the PVC liner and the smaller ones fit the PC liner.

6.3 Liner Material

The PC liner is desirable as it allows direct observations of the core, such as: the amount of sediment recovered, the position of the piston relative to the water-sediment interface, type of material recovered, and severe disturbance (principally cracking). However, there was concern that the smaller diameter of the PC (114 mm) than the PVC (118 mm) would adversely effect the performance of the corer; to satisfy the theoretical considerations in Table 1, the difference between the O.D. of the core barrel and the I.D. of the liner should be as small as possible. A further concern was that the I.D. of the clear liner is less than the I.D. of the cutting nose, 114 versus 118 mm, requiring that material be compressed when it enters the liner. The cores collected with PC and PVC liners, Cores 20 and 21 respectively, with all other variables held constant, were almost identical in length (5.45 m). The compression analysis (Section 5), revealed the PVC liner (Core 21) actually has a higher compression (by approximately 8%) than the PC liner (Core 20), however, it penetrated farther into the seabed and recovered material from greater depth (Table 4).

During SCARAB98 (April 1998) and the CET, considerable variability in the diameter of core liners has been observed, particularly with the PC liner. The variability is more pronounced between different pieces of core liner, than along the length of a single piece. Apparently this is a result of the manufacturing procedure, the PVC being extruded while the PC is spun. Variability in core liner diameter must be recalled when making laboratory measurements of sound speed. These measurements are made relative to a known reference, traditionally a representative piece of core liner with distilled water at known temperature, and then corrected to bottom water conditions at a core location (based on CTD measurements). Whenever possible, the sound speed of the water in the core above the water-sediment interface is measured and compared with in situ conditions as a means of checking this calibration technique. Alternatively, if there is concern about variability in the diameter of pieces of core liner, the sound speed measurements of the water above the water-sediment interface should be used as the basis of the calibration (Holland, Personal Communication).

6.4 Rigging

To prevent the piston from being pushed upward under hydrostatic pressure as the corer enters the water, it is advisable to fill the core barrel with water before lowering it. In addition, a piece of twine tied between the core nose and piston also prevents the piston from moving prematurely.

When the PC liner is used, a short piece of the PVC liner may be used to prepare the joint between 4 m sections of PC liner. As the I.D. of the PVC liner is just slightly less than the O.D. of the PC liner, it may be used to prepare a sleeve that reinforces the joint. Note that the edges of the liner in the upper barrel should be filed to allow the piston to pass without getting jammed on a protruding lip. It is possible that some water gets sucked into the core at the joint. While this may reduce the effectiveness of the piston, it may also prevent the core from being stretched.

The effect of adding additional weight to the corer could not be tested at CS2 because the pelican hook in use at that site was not certified for loads in excess of 800 kg—the weight of the reference configuration (Core 20). Lastly, it has been observed that mud

adheres more readily to the lower 4 m section of core barrel. The top 4 m section has a noticeably smoother surface. It is possible that some improvement in performance may be realized by polishing the lower section of pipe to reduce the friction on this surface.

6.5 Gravity Coring

The focus of the CET was the development of piston coring capabilities at SACLANTCEN. Nonetheless, several important insights into the operation of SACLANTCEN gravity coring equipment were also noted. Contrary to using the piston corer, the winch operator should continue to let out cable (approximately the length of the coring device) once the gravity corer begins to free-fall or after initial contact with the seabed if it is being winched into bottom. It is important (especially in a free-fall configuration) that the opening at the top of the core barrel be sufficiently large to allow the water above the incoming sediment to escape without a force resisting the incoming sediment. The flow of water through valves (which close on recovery to create a vacuum to aid in retaining the sample), such as that on the SACLANTCEN OEG corer, should be checked.

For long cores in soft material, the penetration of the corer into the bottom is not improved by free-falling. Cores 14 and 15 at CS2 used the SOPROMAR gravity corer in free-fall and winched-in modes respectively. Both penetrated approximately 6.8 m (about 80 cm up the core head) and recovered 3.2 and 3.5 respectively (in addition, Core 15 did not close properly and approximately 30 cm of material was hanging below the nose). For the lighter SW104 corer designed for collecting 1 m cores, the performance was better when used in a free-fall configuration. Cores 19 and 18 used the SW104 corer in free-fall and winched-in modes respectively. In both cases, the full barrel penetrated, but 1 m was recovered in Core 19 compared to 0.4 m in Core 18.

6.6 Core Handling

Once recovered, care must be taken to minimize further disturbance of the core during its handling. In this regard, the practice of cutting the core liner using a hacksaw tends to shake the core considerably even when it is being held firmly. Moreover several cuts are often required, as described in Section 3. GSC-Atlantic have a device that incorporates a circular clamp and a knife blade that can rotate around the liner, increasing the depth of the cut with each rotation (Bob Murphy, Personal Communication). It functions similar to a pipe cutter, but the circular clamp distributes pressure evenly around the core liner to prevent deformation of the core.

SACLANTCEN typically stores and transports its SW104 cores in a vertical orientation to minimize disturbance of the sample and allow water to be retained above the water sediment interface. For longer cores (> 2 m), this would require that the cores be cut in shorter pieces. However, sectioning the cores disturbs the material and precludes the measurement of sound speed and magnetic susceptibility within approximately 0.15 and 0.20 m respectively of the end of a core section. Accordingly, horizontal transport and storage of cores in longer sections (4 m) is preferable and is possible after the insertion of a bulkhead to maintain the water-sediment interface. During the CET, the bulkheads

were formed by disks of high density foam pushed down the core liners until they reached the water-sediment interface. The disks have a single central hole (to allow fluid to flow past the disk during its placement) that are plugged once a disk is in position. During a subsequent trial, GEOSCAT99, the technique for placing the foam disks and plugs was improved by developing a tool specifically designed for this purpose (Fig. 11). For future consideration, the bulkheads could be made of two PVC discs, an o-ring gasket that can be tightened to seal the edges against the core liner, and a bleed valve that is open when the bulkhead is being lowered into position.

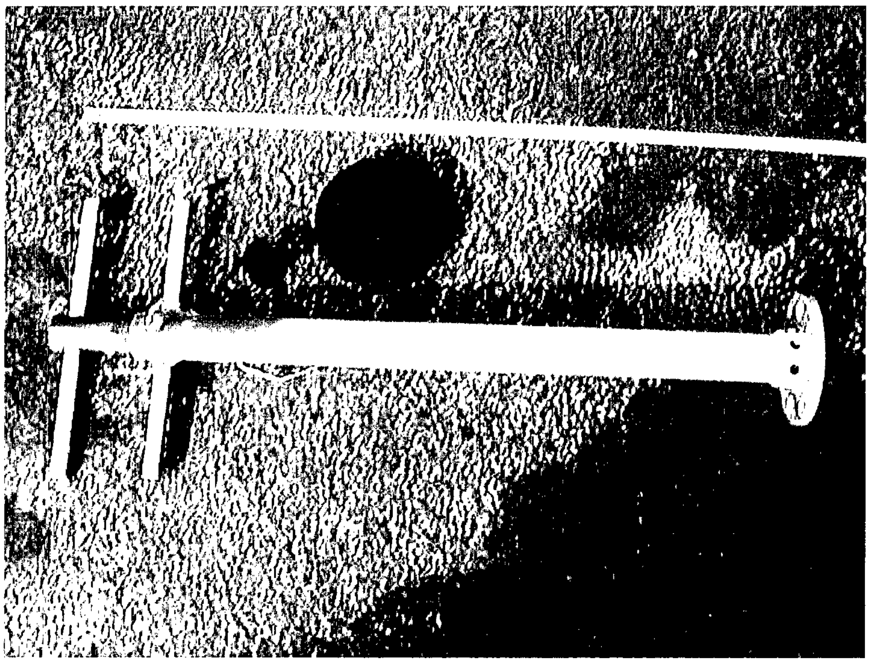


Figure 11 *Device used for placing foam disk bulkheads in the core liner at the water-sediment interface. After the outer tube and flange assembly have been used to place the disk, the inner rod is used to place the foam plug in the central hole in the disk. Overall length is approximately 70 cm.*

7
Conclusions

When properly configured for a given environment, the University of Bologna piston corer (a variant of the SACLANTCEN Sphincter piston corer) can recover cores with only minor disturbance. At an experimental site in the Capraia basin, with a seabed composition dominated by silt and clay with some thinner layers of shells and sandier material, cores of 5 to 6 in length were recovered. Some 0.35 to 0.40 m of material is routinely missing from the top of the core, however, this is characteristic of piston cores as the water in advance of the piston displaces sediments at the water-sediment interface. When the corer performs well, the material in the core is compressed by approximately 10%, while the compression may be considerably higher, 25 to 35 %, if it the corer is not properly configured or does not function properly (e.g. piston did not split). The compression estimates are based on an analysis of magnetic susceptibility measurements of multiple cores collected at the same location in the Capraia Basin. Core lengths are restored to those *in situ* by aligning the nulls in the measured magnetic susceptibility responses using a linear compression function and a depth offset. Laboratory measurements of sound speed compare favourably with a geo-acoustic model for the same site, CS2, based on a time domain inversion of wide-angle reflection data and frequency domain modelling of bottom loss data (Holland and Osler, 1999).

Critical factors in the preparation and operation of the piston corer include the piston design and friction against the liner, the strength of the shear pins, the cable lengths, and winch speed. Factors that have a less significant influence include the liner material, PVC or PC, and free-fall height.

8
Acknowledgements

The Geological Survey of Canada – Atlantic provided the services of their coring specialist, Mr. Bob Murphy. His expert advice and experience were extremely valuable in improving and refining the piston coring techniques employed at SACLANTCEN.

References

Busatti, G., Magagnoli, A., Mengoli, M., 1980, Carotiere a Gravita' da 1.2 T, Rapporto Tecnico n. 13, CNR - Instituto per la Geologia Marina, Bologna.

Hamilton, E. L., 1980, Geoacoustic modeling of the seafloor, *Journal of the Acoustical Society of America*, **68**, 1313-1339.

Holland, C.W., Osler, J.C., 1999, High resolution geoacoustic inversion in shallow water: A joint time and frequency domain technique, SACLANTCEN SM-361.

Holland, C.W., Osler, J.C., Nardini, P., Turgutcan, F., 1999, SCARAB97; Capraia Basin, Northern Tyrrhennian Sea: Environmental Data Compilation, SACLANTCEN CD-22.

Hvorslev, M.J., 1949, Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes, U.S. Army Corps of Engineers, Waterways Experimental Station, Vicksburg, Miss., 512 pp.

Kermabon, A., Blavier, P., Cortis, U., Delauze, H., 1966, The *Sphincter* corer: a wide-diameter corer with watertight core-catcher, *Marine Geology*, **4**, 149-162.

Kermabon, A., Gehin, C., Blavier, P., 1968, Numerical results of the analysis of sea-bottom cores, Volume 1, Naples and Ajaccio Zones, SACLANTCEN M-46.

Kermabon, A., Matteucci, B., 1970, Mounting Instructions for SACLANTCEN's 120mm Sphincter Corer and Hints for its Use, SACLANTCEN M-69.

Magagnoli, A., Mengoli, M., 1995, Carotiere a Gravita' *SW 104*, Rapporto Tecnico n. 27, CNR - Instituto per la Geologia Marina, Bologna.

Document Data Sheet

Security Classification	Project No.
UNCLASSIFIED	04-C

Document Serial No.	Date of Issue	Total Pages
SR-321	November 1999	34 pp.

Author(s)

Osler, J.C., Gualdesi, L., Michelozzi, E., Tonarelli, B.

Title

Piston coring capabilities at SACLANTCEN: minimizing and assessing core disturbance.

Abstract

Piston and gravity coring and techniques used to collect samples of seabed material. There are many variables that can be adjusted when operating a piston corer, such as free-fall height, core liner material, weight, piston friction, rigging and winch speed. In order to develop a capability at SACLATNCEN to collect longer cores with minimal disturbance, the aforementioned variables were adjusted in a systematic manner in order to determine their relative effects. During the Coring Engineering Trial in March 1999, multiple cores were collected at an experimental site in the Capraia basin, north of Elba Island, where a geo-acoustic model has been developed based on a time domain inversion of wide-angle reflection data and frequency domain modelling of bottom loss data. The disturbance of the seabed material during the coring process may have an adverse effect on its physical properties, such as sound speed, magnetic susceptibility, and bulk density. Accordingly the amount of compression in each core has been estimated by an analysis of magnetic susceptibility data, correlating and aligning nulls in the response. Laboratory measurements of sound speed and bulk density on three of the cores have been compared with each other and with the geo-acoustic model.

From a seabed dominated by silt and clay material with some thin layers containing shells, the properly configured piston corer was able to recover cores of 5 to 6 m in length with a compression of approximately 10%. When it is not properly configured or does not function properly, the compression may be considerably higher, 25 to 35%. Critical factors in the operation of the piston corer included the piston design, the piston friction against the liner, the strength of the shear pins, the cable lengths and the winch speed. Factors that are less significant include the liner material and free-fall height. The laboratory measurements of bulk density are higher that those determined for the geo-acoustic model but may be explained, in part, by the compression of the material during coring.

Keywords

Issuing Organization

North Atlantic Treaty Organization
SACLANT Undersea Research Centre
Viale San Bartolomeo 400, 19138 La Spezia, Italy

[From N. America: SACLANTCEN (New York) APO AE 09613]

Tel: +39 0187 527 361
Fax:+39 0187 527 700

E-mail: library@saclantc.nato.int

The SACLANT Undersea Research Centre provides the Supreme Allied Commander Atlantic (SACLANT) with scientific and technical assistance under the terms of its NATO charter, which entered into force on 1 February 1963. Without prejudice to this main task - and under the policy direction of SACLANT - the Centre also renders scientific and technical assistance to the individual NATO nations.

SACLANT Undersea Research Centre
Viale San Bartolomeo 400
19138 San Bartolomeo (SP), Italy

tel: +39 0187 527 (1) or extension
fax: +39 0187 527 700

e-mail: library@saclantc.nato.int

NORTH ATLANTIC TREATY ORGANIZATION